Lead Corrosion & Control

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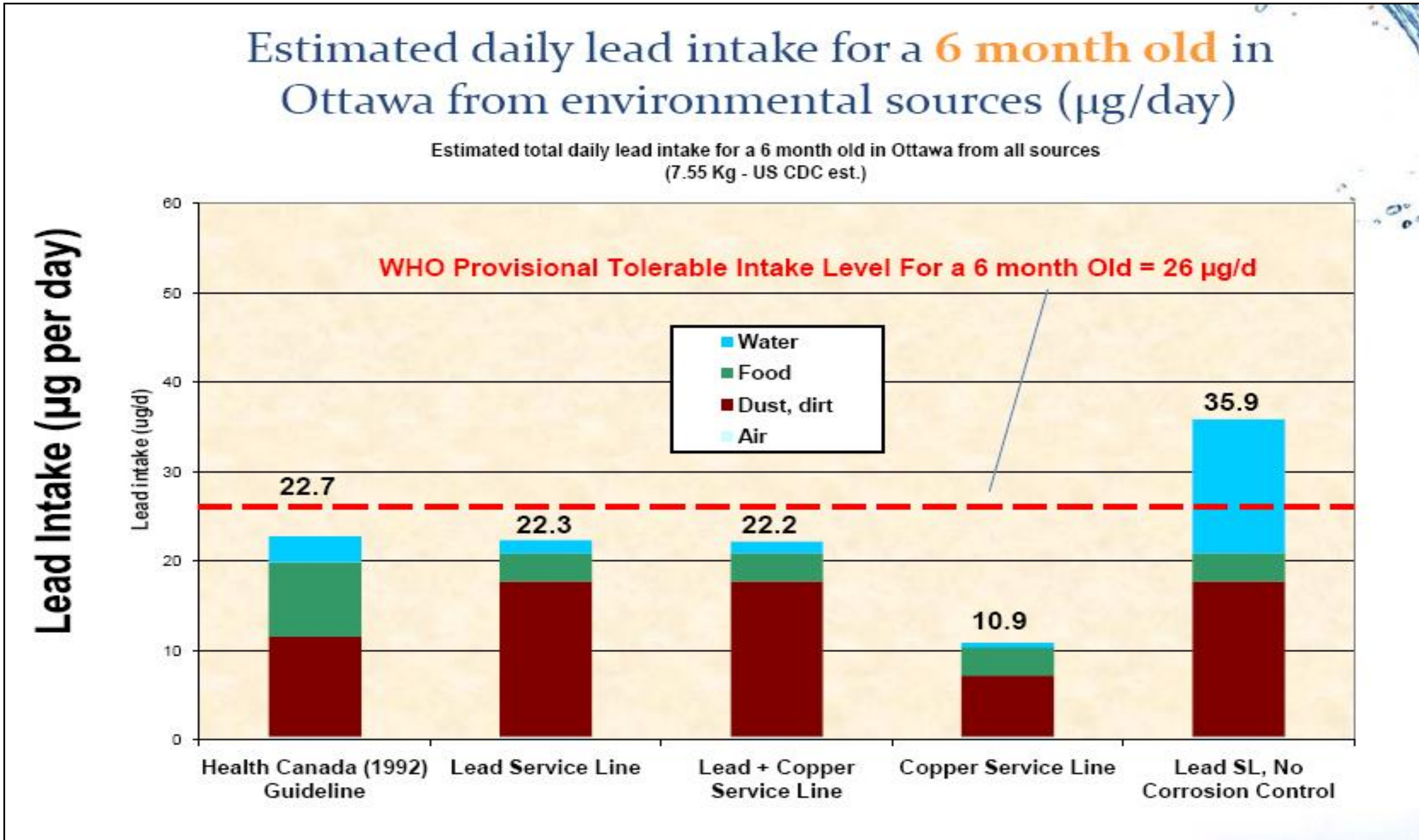
Presentation Outline

- Background
- Corrosion chemistry in drinking water
- Corrosion control methods
- Bench-top corrosion research tools
- Long-Term LCR Revisions and impacts
- Take home messages
- LCR monitoring case study -LWC

Daily Lead Intake: Water vs Other Sources



Drinking water normally is not a major source of lead exposure. It can be a significant source under the condition of lead service line with no corrosion control.

Water Lead/LSLs Correlated to Blood Lead: Europe

- Lead in water > 5 ppb significantly increased blood lead ($p > 0.001$) in young women, and intervention excluding tap water a few months dropped blood lead 37% (Fertmann et al., 2004)

- Children in France (6 months-6 years) had 50% higher blood lead if they consumed tap water and had an LSL, and the 95%'ile blood lead level for this group was increased by 256% (Etchevers et al., 2014)

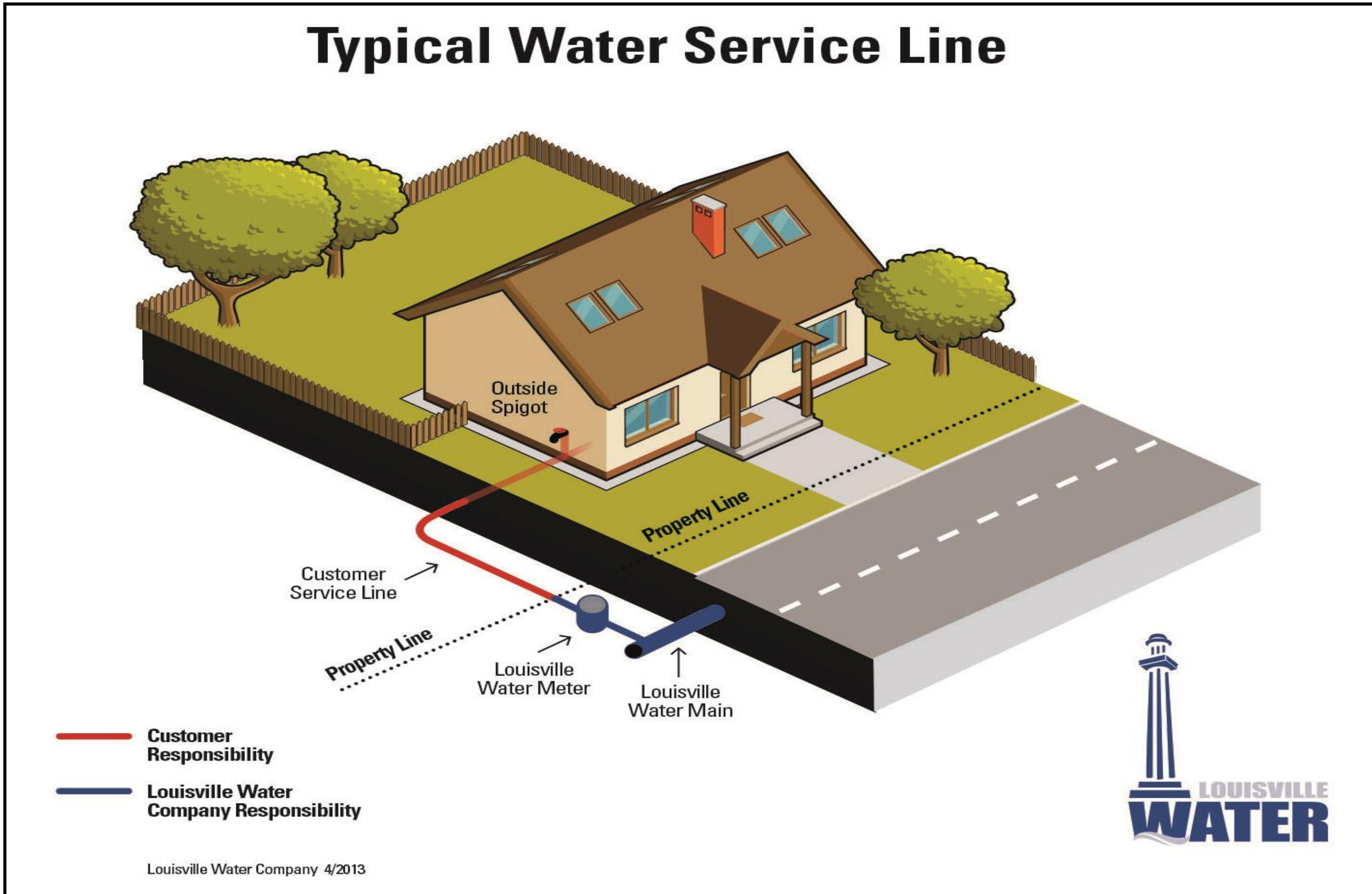
Historical Corrosion Management

- Iron corrosion
  - Prevent Tuberculation
  - Prevent pipe loss
  - Prevent red water
- Controlled by
  - Ferric oxides & calcium carbonate films at pH >8
  - Polyphosphate addition –NOT orthophosphate

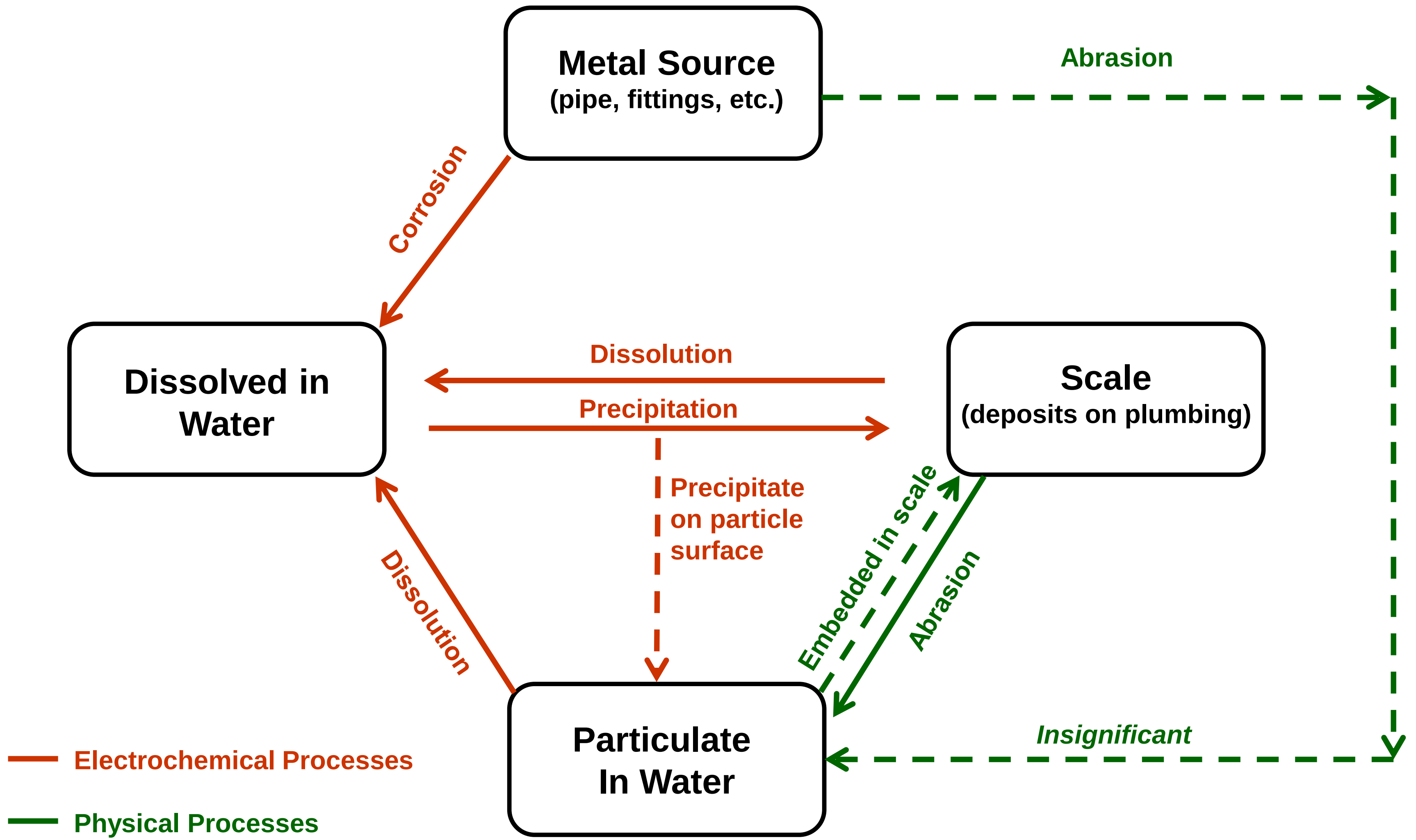
Historical Corrosion Management

- Copper corrosion
  - Prevent pitting corrosion
  - Prevent uniform (general) corrosion
- Controlled by
  - Prevent microbiological growth
  - Maintaining low DIC/high pH
  - Allowing time for films to form
  - Orthophosphate – ongoing treatment but must be maintained

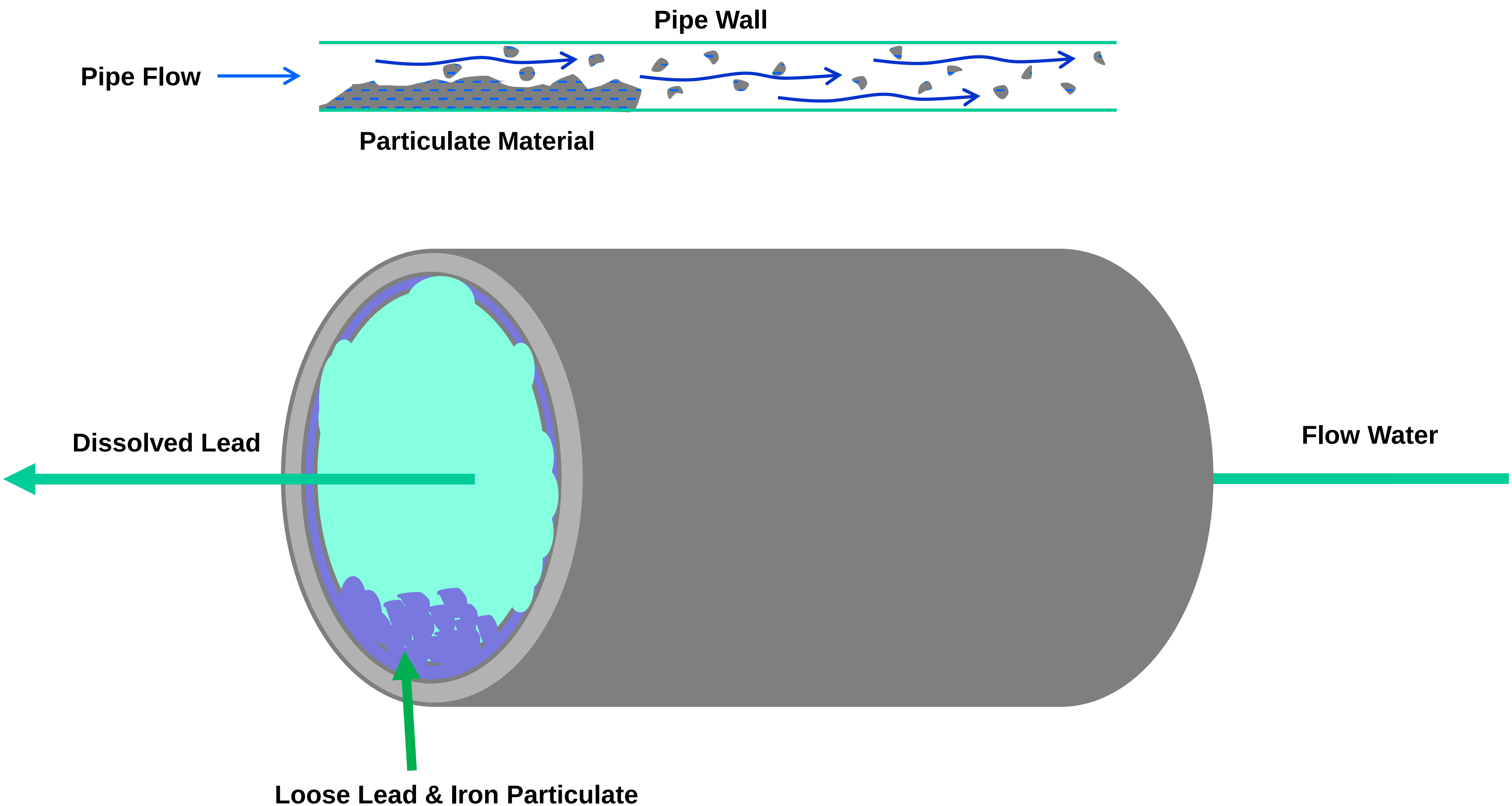
Lead Sources from Water Service Connections



Lead in Drinking Water



Water with Dissolved Lead and Lead Particulate



Abrasion

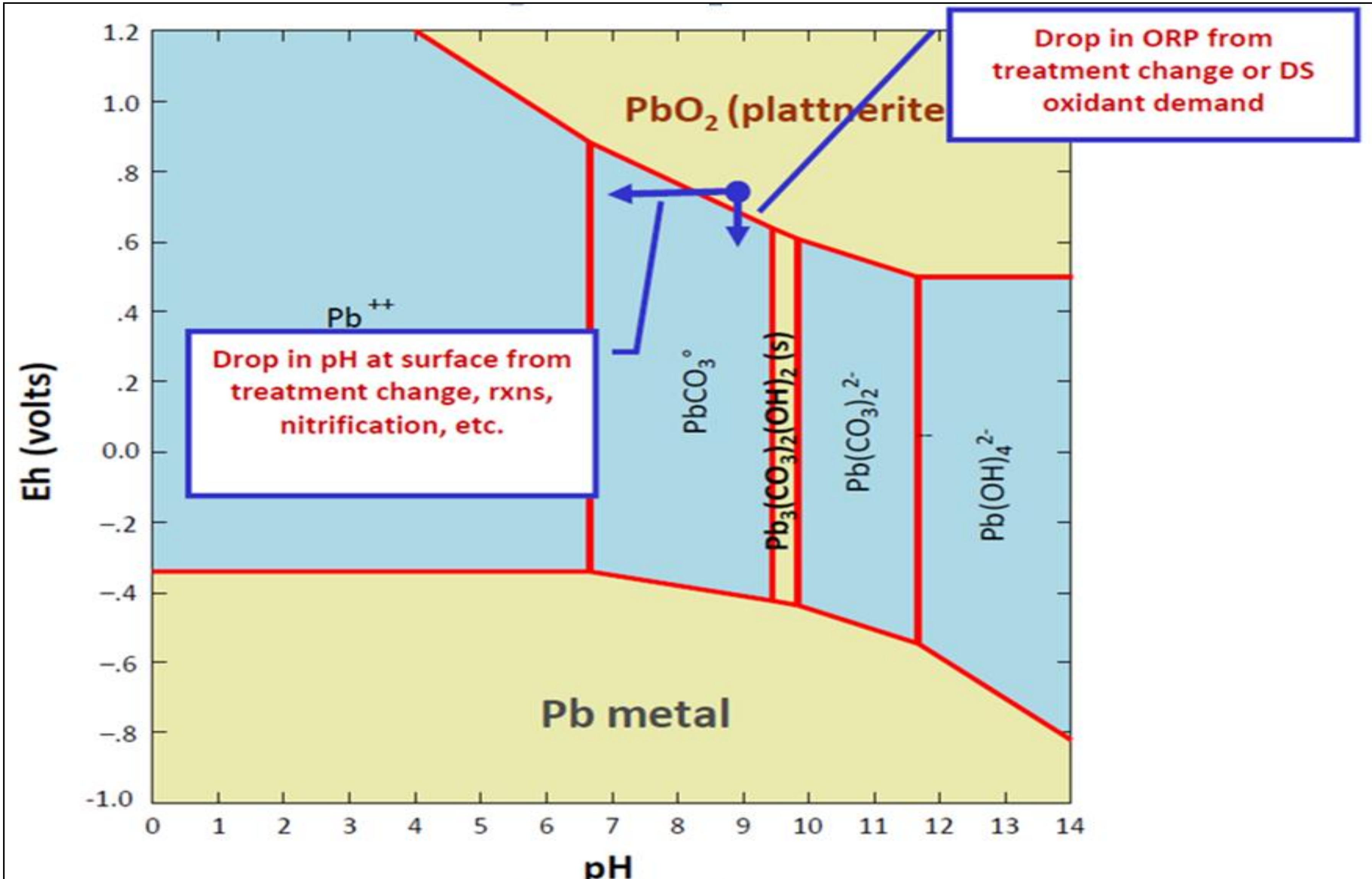
- Physical disturbances
  - Meter installation/replacement or damaged
  - Service line repair or partial replacement
  - External shut-off valve repair/replacement
  - Street excavation or construction near the house
  - Any part of home plumbing system disturbance
- Hydraulic factors
  - Significant flow changes
  - Flow reversals
  - Pressure transients

Corrosion Basics

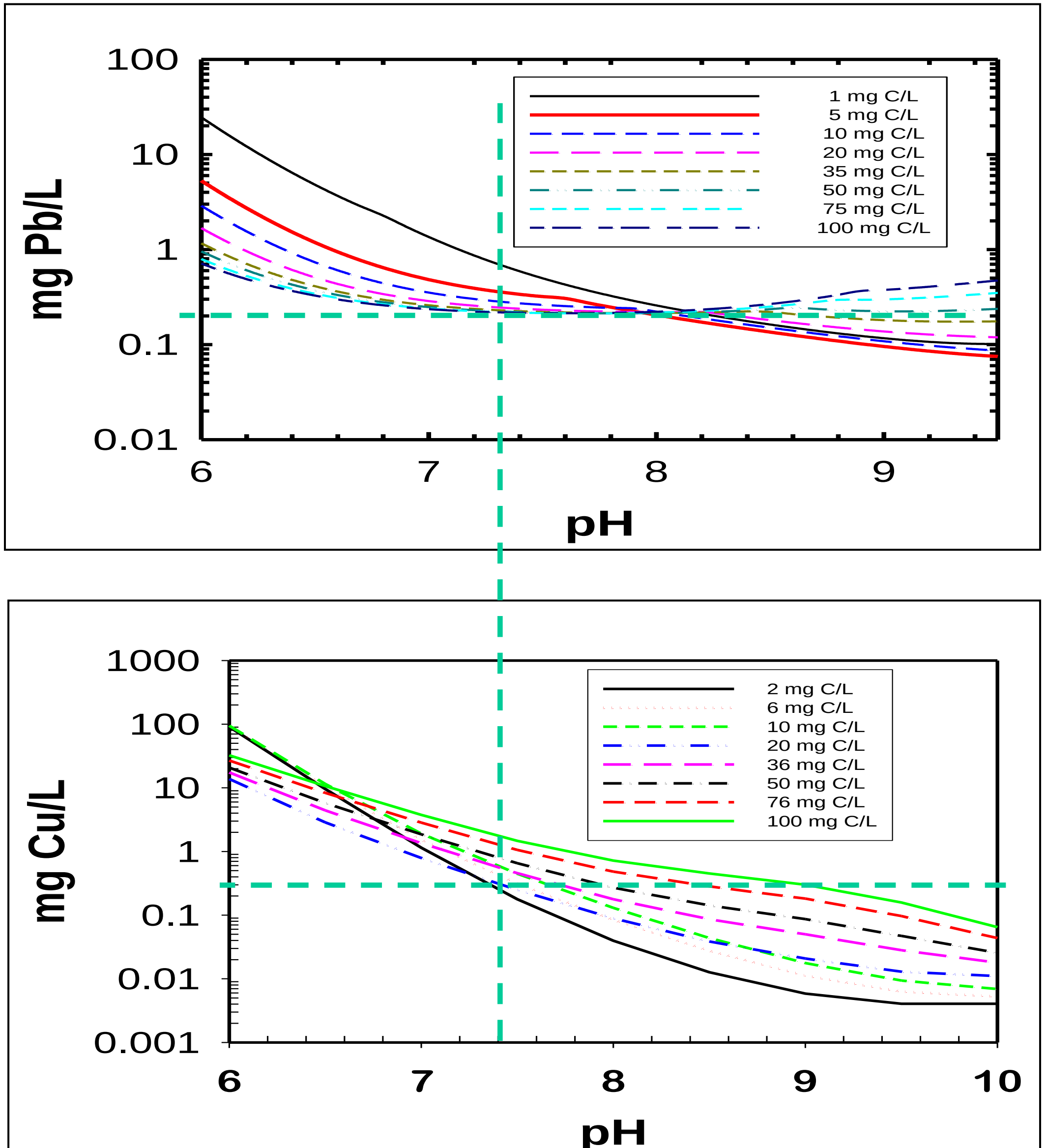
- Corrosion in drinking water: An electrochemical interaction between metal surface and water, resulting in metal release into water
  - Reduction @ Cathode: $2e^{-} + 1/2O_2 + H_2O = 2OH^{-}$
  - Oxidation @ Anode: $Me = 2e^{-} + Me^{2+}$
- Types of corrosion
  - General or uniform
  - Non-uniform: galvanic, pitting, microbial
- Complex processes
  - Pipe material and plumbing practice
  - Water quality factors (pH, DIC, ORP, PO_4^{3-}, Cl^{-} and SO_4^{2-} ...)
  - Hydraulic conditions

Lead Eh-pH Diagram in Water

(DIC=18 mg/L & Pb=0.010 mg/L)



Impact of pH and DIC on Pb and Cu



- Higher pH better for both
- Optimal DIC for Pb depends on pH
- Lower DIC better for Cu at all pH > ~7.2 and for Pb at pH >~8.2

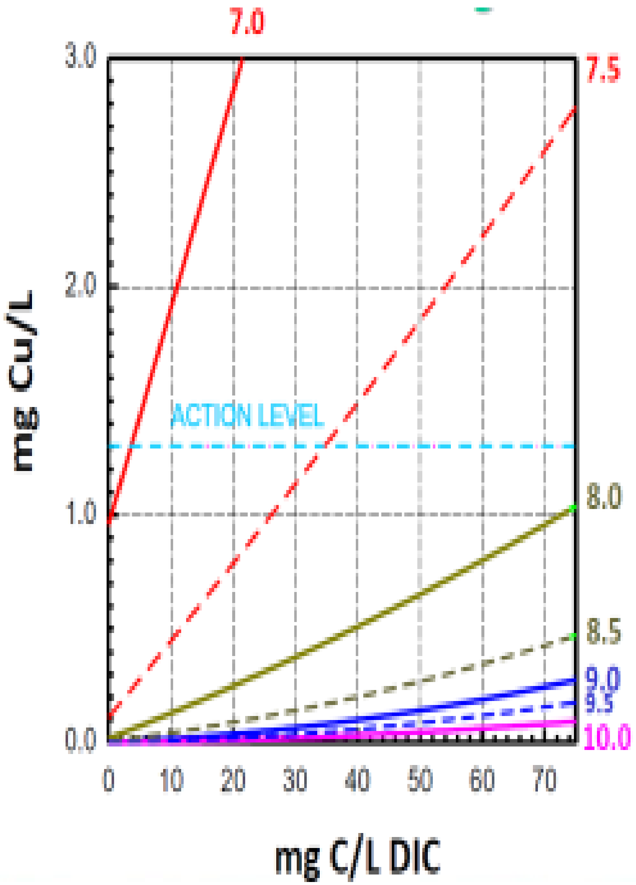
How to Minimize Corrosion

- pH/alkalinity/DIC
  - High pH and low DIC
- Orthophosphate (PO_4)
  - Best at pH 7.2 to 7.8
  - Issues: microbial? wastewater P?
- *Form insoluble Pb(IV) scale*
  - *High oxidation state, e.g., via maintenance of free chlorine residual*
- Cl/SO4 Ratio
  - Higher chloride-to-sulfate mass ratio (CSMR) tends to increase lead release under the conditions of galvanic corrosion
  - CSMR<0.5

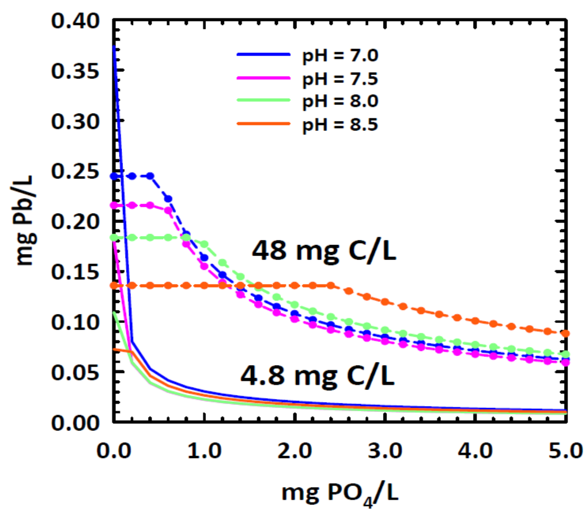
pH Adjustment

- Pb and Cu release generally decreases with pH increase from solubility point of view under most conditions. Raise pH in 0.3 unit increments towards 9-9.5 is recommended by EPA as a Pb control strategy if current pH is >7.8 and DIC >5 mg C/L

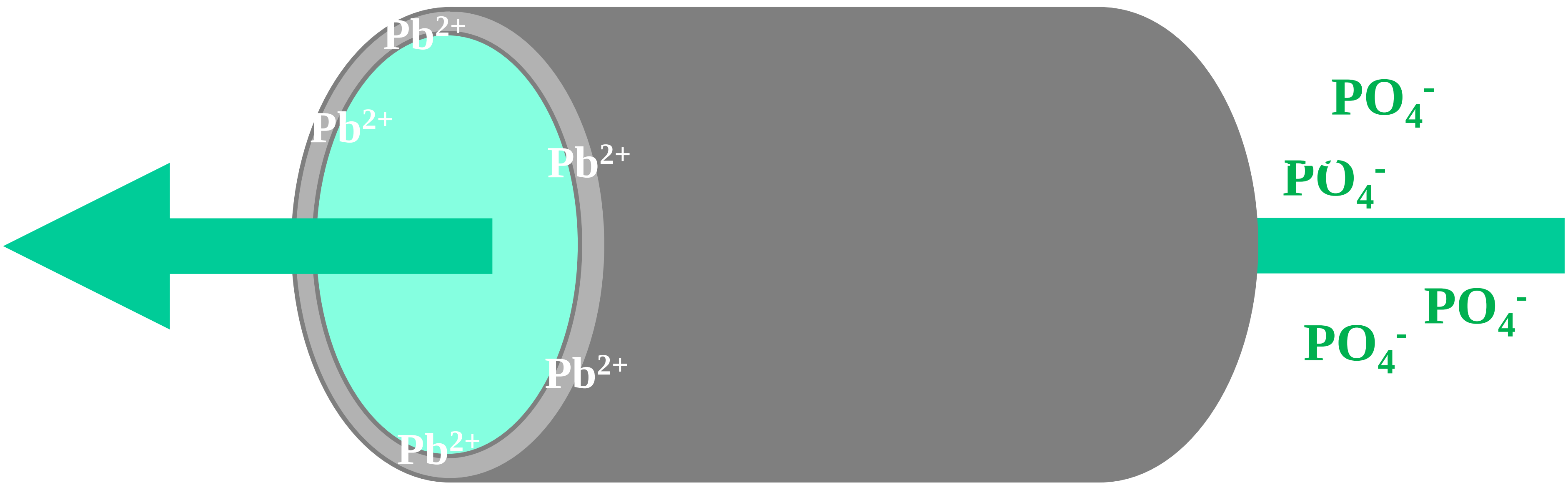
- pH adjustment may not always work when
  - pH not high enough throughout DS and need buffering (water blending, nitrification, CO2 exchange in tanks)
  - Dissimilar material on pipe surface or other corrosion mechanisms



Orthophosphate Application

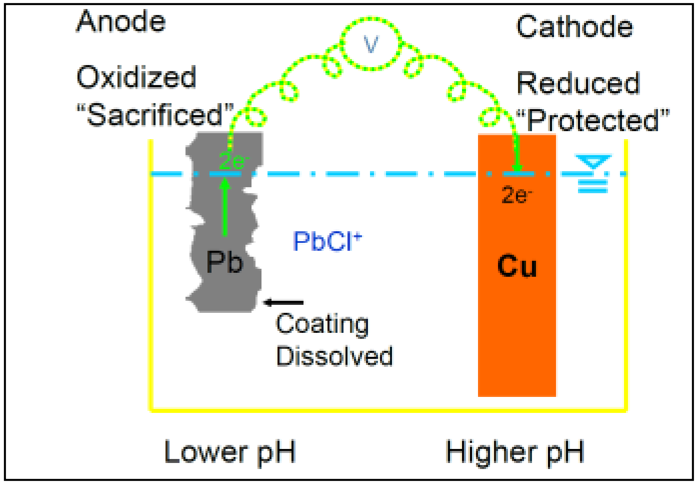


- More effective with low TIC
- Lower dosages at low TIC
- Point of diminishing returns higher with high TIC

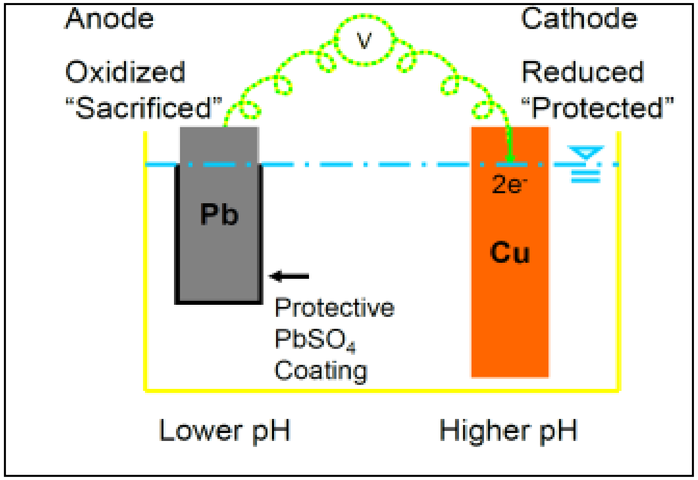


Effect of CSMR

- Higher chloride-to-sulfate mass ratio (CSMR) tends to increase lead release under the conditions of galvanic corrosion

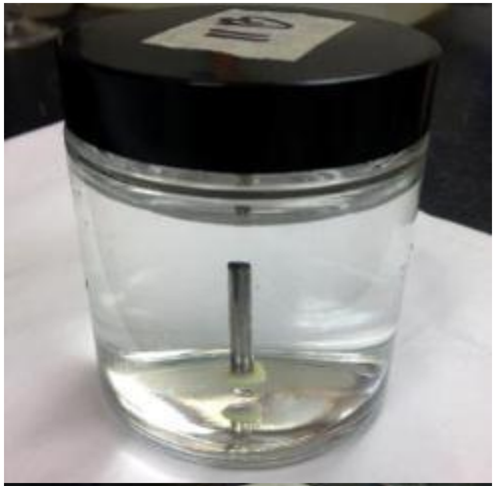


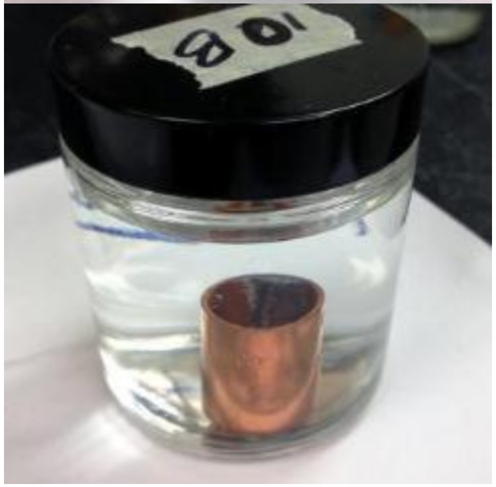
- A threshold CSMR of 0.5 was reported: Significant lead leaching may occur when CSMR > 0.5



Bench Scale Research Tools

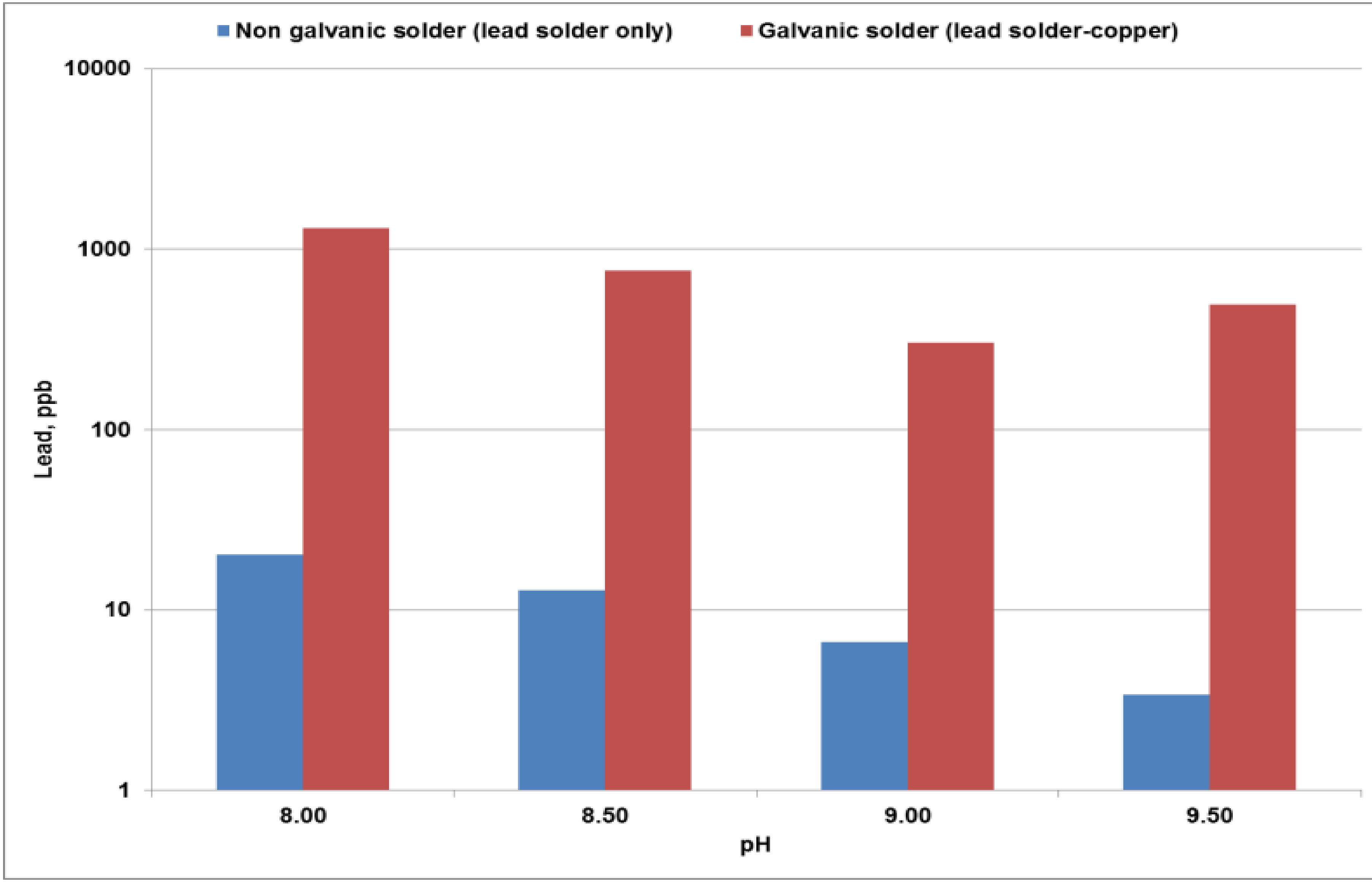
- Two Types of coupons can be used
  - Non-galvanic solder (NGS) coupon - 50:50 Pb:Sn solder, 1" /1/8" (L/D), epoxied to the bottom of a 120 mL glass jar
  - Galvanic solder (GS) coupon -50:50 Pb:Sn solder placed inside copper coupling (right picture)
    - 50:50 Pb:Sn solder - 1"/1/2" (L/D)
    - Cu coupling – 1.2"/5/8" (L/D)





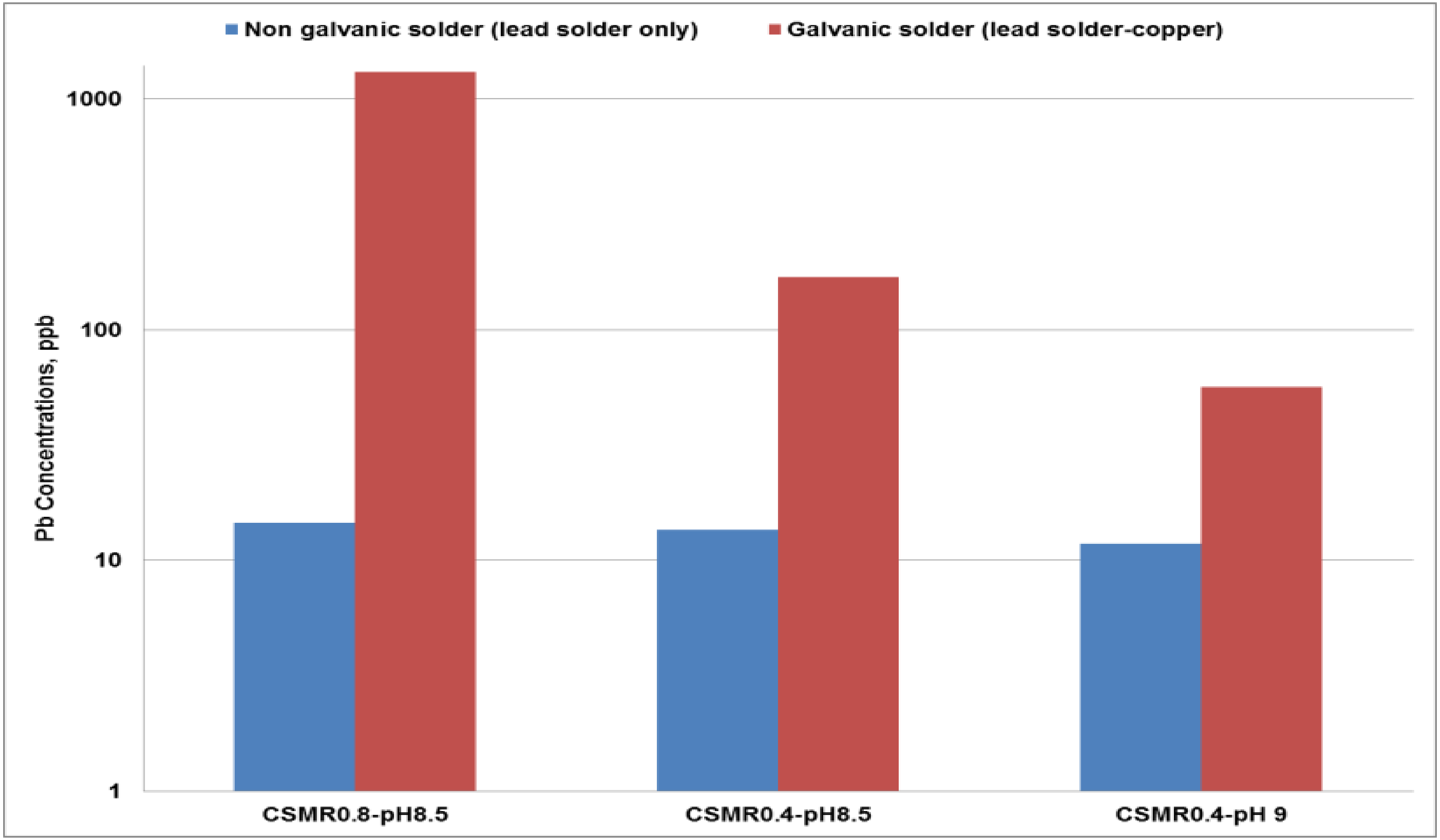
pH Effect on Pb Release

(Average lead levels over 2 month study)



CSMR and pH Effect on Pb Release

(Average lead levels over 2 month study)



Lead and Copper Rule (LCR)

- Promulgated 1991
- Sample “first flush” in selected homes with great likelihood of high Pb levels (LSLs or Pb solder)
- Number of locations depends on system size
- Action Level (AL)
  - 0.015 mg/L for Pb, 1.3 mg/L for Cu
  - Exceedance of is NOT an MCL violation, but can trigger other actions (TT)
    - Optimized Corrosion Control Treatment (OCCT)
    - Water quality parameter (WQP) monitoring
    - public education, and
    - lead service line replacement (LSLR)
- 2000 & 2007
  - Minor revisions – rule framework basically unchanged

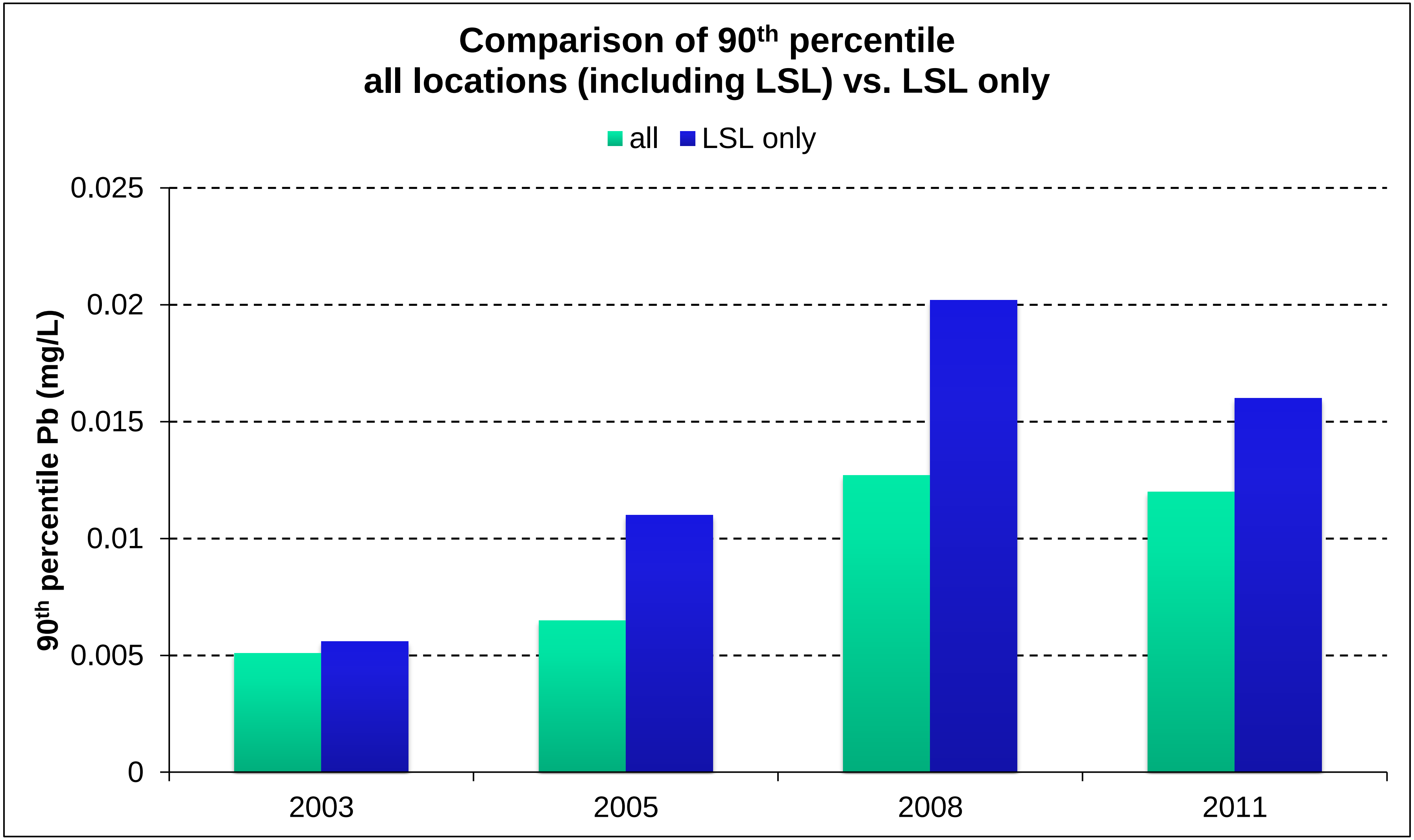
Long-Term LCR

- Long-Term LCR (LT-LCR)
  - Scheduled to be proposed by USEPA sometime in ~~2013~~ ~~2014~~ ~~2015~~ 2017?
  - Likely promulgated two years later
  - May include
    - Revisions to sampling
    - New or re-emphasized OCCT
    - PLSLR and other LSL issues
    - AL?

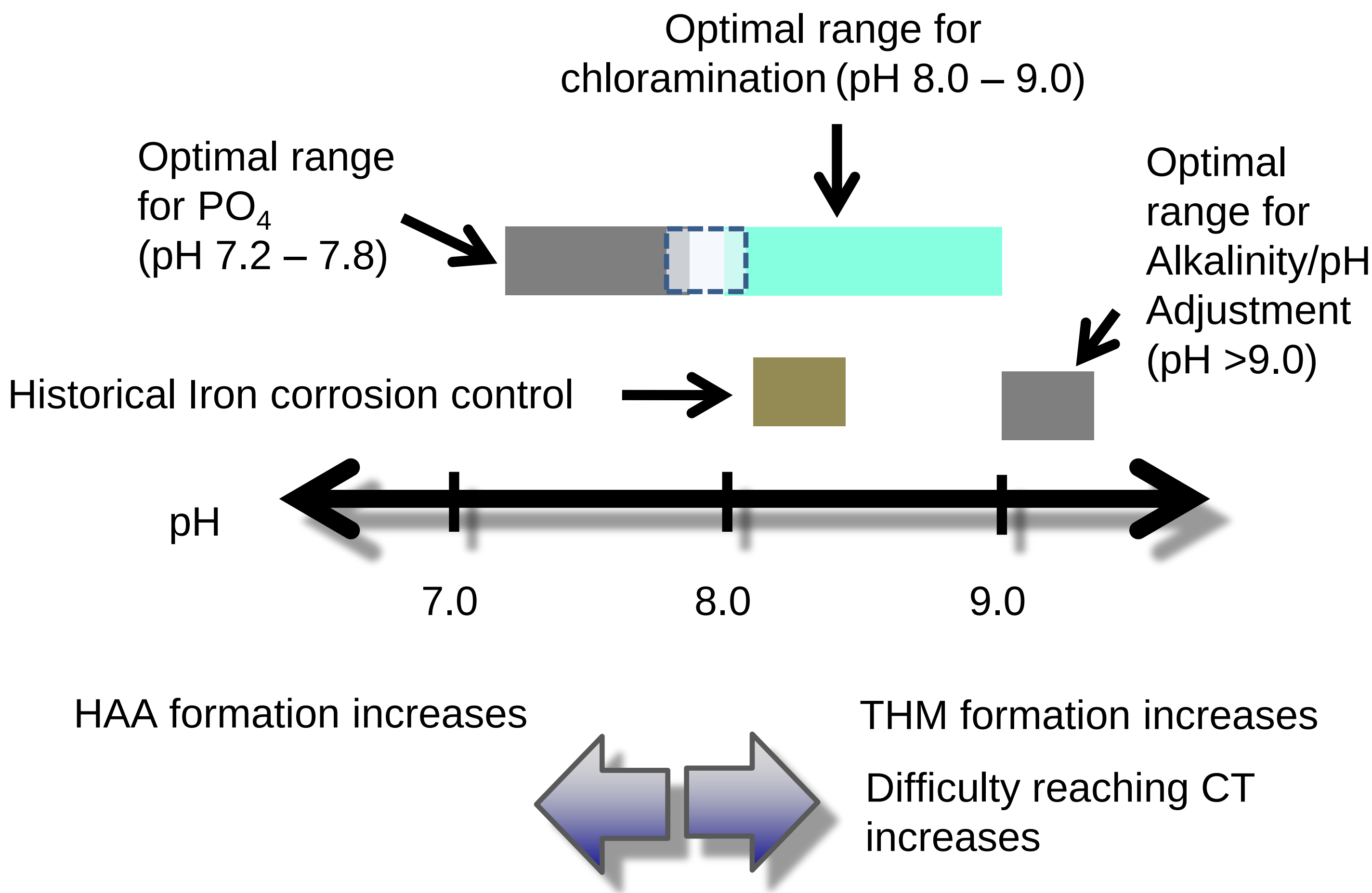
LTLCR – Potential Impact of Revisions

- Some systems currently in compliance need to
  - Re-assess current OCCT
  - Change OCCT
- Change LSL replacement activities
- Repeat OCCT studies (pipe loops)
- Separate Cu and Pb
- Only or More LSLs as Tier 1 sites
- Change sampling protocol
- Lower AL
- More WQP
  - More sites
  - Higher frequency
  - Use control charts
- Public Education

90th Percentile Lead Levels: All vs LSL Only



Balancing Multiple Regulations: DBP Example



Take Home Messages

- Personal involvement from top management
- A WQ team from across the company
- A WQ surveillance team with internal and external customers
- Be proactive: 5Cs (character, comprehensiveness, communication, commitment, and creativity)
- Define WQ signal from noise
- Review historical data to calculate 90^{th} percentile using only LSL locations
- Profile (ten 1L samples) at selected homes
- Investigate high velocity flushing after LSL replacement
- If close to AL or ~8 ppb, look at Pb control alternatives (PO4)

Take Home Message

- **Three levels of WQ issues (Result-code)**
  - System-wide: treatment plant related (water source or and/or source WQ changes, treatment changes/loss of treatment control, unstable water leaving the plant(s)
  - Area-wide/Zip code: distribution tanks/reservoirs, major water-main breaks, downstream low demand, nitrification, etc.
  - Individual customers: low water use homes may perpetually have high lead; stagnation can affect protective scales within LSLs; LSL disturbances happen daily
- **Distribution water quality management**
  - Customers drink tap water not finished water in clear wells
  - Water quality can change as it travel from the plant to customer taps: pH drop, nitrification, bio-chemical reactions

LCR-Year Monitoring Case Study

- Develop strategy to improve site representativeness and sample integrity – *Noise Reduction*
- Establish team involving all key departments
- Historical data review
- Identify factors that may inadvertently alter sample representativeness – *False Signal*
- **Irregular/abnormal** distribution and/or residential disturbances
- Customer performs the sampling

LCR-Year Monitoring Case Study

3C's Required For Success:

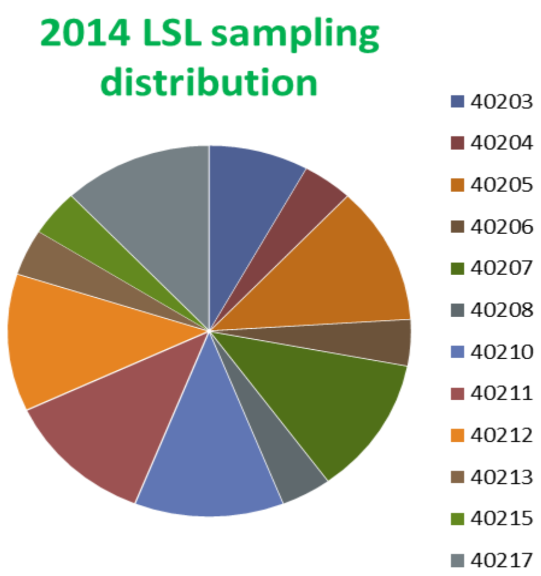
<u>C</u>ommunication + <u>C</u>ommitment + <u>C</u>ollaboration

Quarter	LCR Tasks
Q1	➢ Form team with support from executive leadership ➢ Establish communications with team members & state regulators ➢ Initiate surveying of LCR sample sites
Q2	➢ Collect field & residential information to finalize sample list ➢ Verbal & written communications with customers ➢ Upload all LCR sample sites into Go!Sync mapping tool for field users ➢ Begin sample collection: coordinate delivery & pick-ups of samples
Q3	➢ Continue sample collections through September ➢ Laboratory analysis and reporting ➢ Customer result notifications
Q4	➢ Calculate 90th percentiles, finalize all reporting

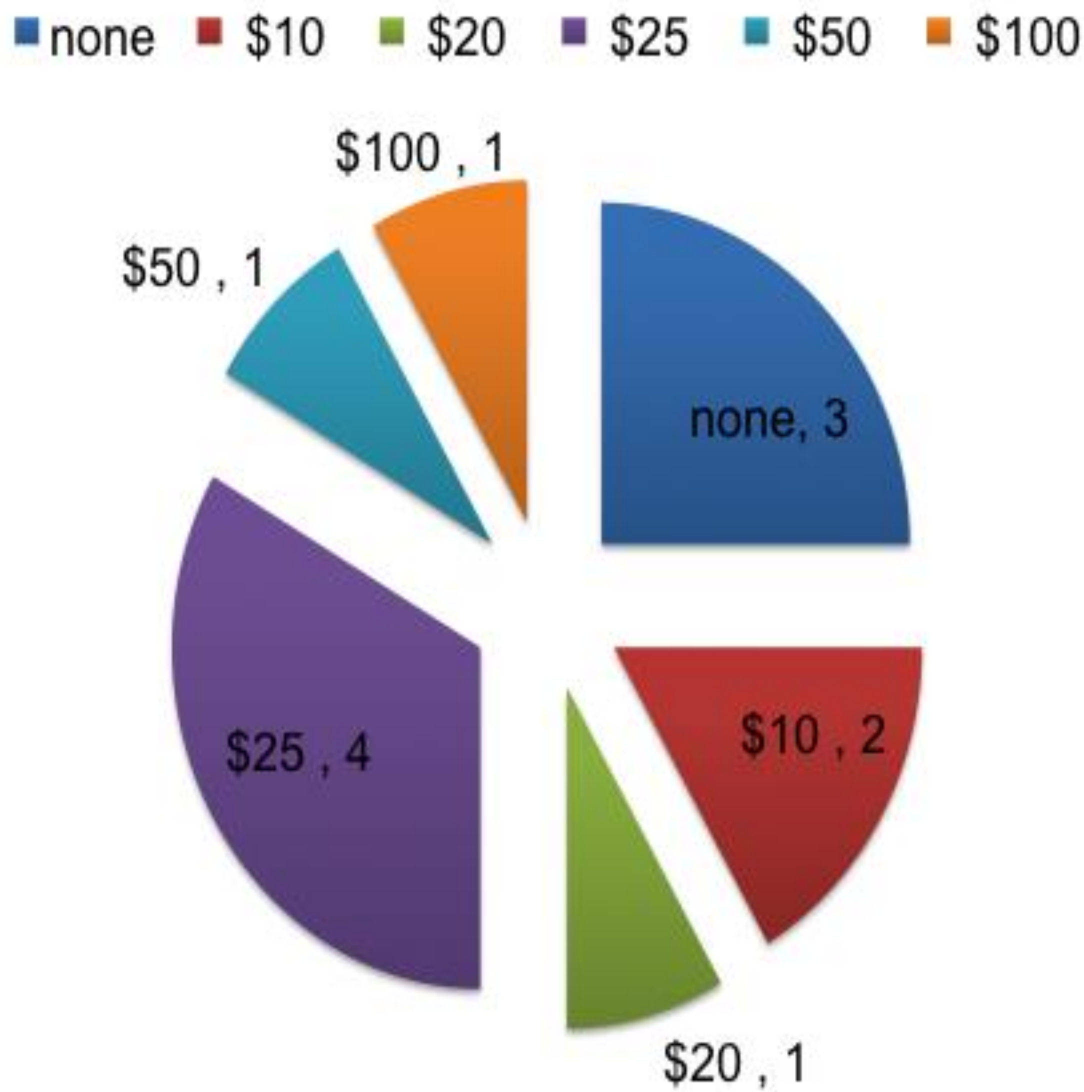
TIMELINE	LCR TASKS
JAN - MAR	➢ Establish quarterly meetings (Engineering, Water Quality, Plant Operations, Public Relations, Distribution Logistics, GIS) ➢ Establish communication with KYDOW: identify regulator overseeing LCR ➢ Use service line records to generate initial list of LSL locations spatially representative of entire DS ➢ Field verify LSL by visual confirmation in the vault ➢ Finalize initial list of LSL locations that could be registered as LCR sites ➢ Set up billing credit with Accounting for participation ➢ Monitor bi-weekly WQP at treatment plant
APR - MAY	➢ Quarterly meeting ➢ Records inquiry for residential information ➢ Gather field information in proximity to LCR sites locations ➢ Finalize LCR sampling locations ➢ Verbal communications with selected customers (2 weeks prior to collection) ➢ Upload all potential site locations into Go!Sync Mapbook ➢ Prepare for laboratory analysis (contract or in house); receive supplies, preservatives, etc ➢ Review customer sampling procedures ➢ Monitor bi-weekly WQP at treatment plant ➢ Collect WQP DS samples 2 weeks apart
JUN - SEPT	➢ Quarterly meeting ➢ Monitor bi-weekly WQP at treatment plant ➢ Send 1^{st} 6-month WQP data to KYDOW ➢ Communicate with customer to coordinate delivery & pick-ups ➢ Confirm no recent activity within sampling zone ➢ Map updates (Mapbook): update active sites, remove sites as samples are collected ➢ Deliver lead collection kits with sampling instructions to selected sites ➢ Collect minimum of 50 samples (equal #: 25 LSL + 25 LSC) ➢ Register new sites with KYDOW ➢ Laboratory analysis & reporting ➢ Customer result notification provided within 30 days of receiving result ➢ Certify results notification to the KYDOW: no later than 3 months following the end of the monitoring period (12/30 or earlier)
OCT - DEC	➢ Quarterly meeting ➢ Monitor bi-weekly WQP at treatment plant ➢ Send Lead and Copper results (plus 90^{th} % sheet) to KYDOW by October 10^{th} ➢ Collect WQP DS samples 2 weeks apart ➢ Send 2^{nd} 6-month WQP data to KYDOW

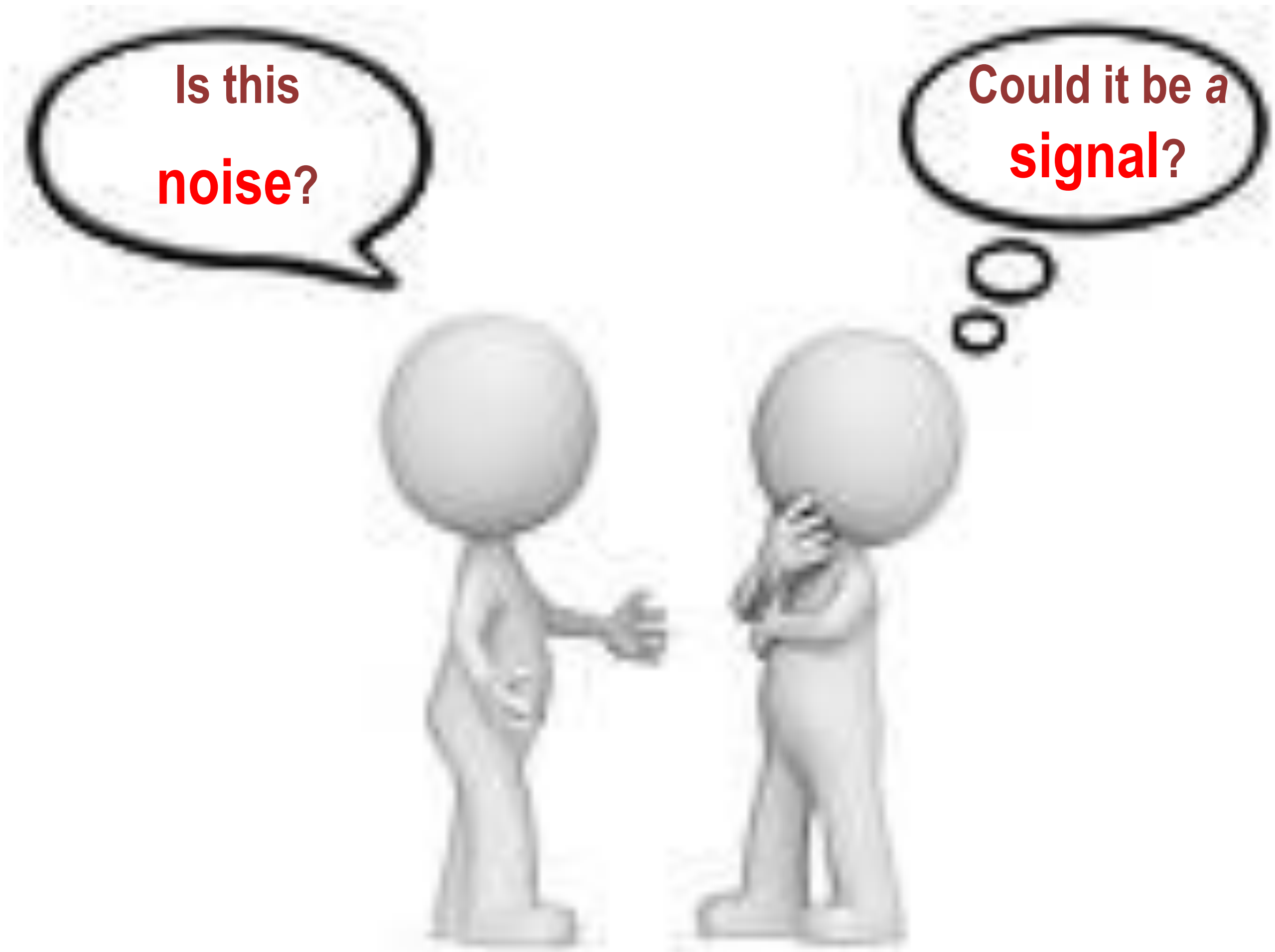
Sample Sites Selection

- Spatial representation of wide DS
- Field verification of LSL
- Identify significant DS impacts in proximity of sample site within a 3 month period prior to collection
- Gather residential information: shut offs, water usage, contact information
- Customer communications: verbal commitment to participate, details about residence, schedule sample collection
- Offer $20 billing credit as incentive



Customer Incentives Sponsored by Water System (credit card, credit on water bill, other incentive)




Is this noise?
Could it be *a* signal?